PCT

422 Rec'd PCT/PTO 21 AUG 2000

FORM PTO-1390 (REV. 1-98) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER: HORY 2.PCT/US

U.S. APPLICATION NO. (If known, see 37 CFR 1.5): 09/622639

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/FR99/00357	17 February 1999	19 February 1998

TITLE OF INVENTION: RAPID PROTOTYPING PROCESS BY LASER SINTERING OF POWDER AND ASSOCIATED DEVICE

APPLICANT(S) FOR DO/EO/US: Arnaud HORY, Jean-Marie GAILLARD and Pierre ABELARD

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. [X] This is a FIRST submission of items concerning a filing under 35 U.S.C. 371.
2. [ ] This is a SECOND or SUBSEQUENT submission of items concerning a filing under 35 U.S.C. 371.
3. [X] This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. [X] A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. [X] A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. [X] is transmitted herewith (required only if not transmitted by the International Bureau).
   b. [X] has been transmitted by the International Bureau. (see PCT/IB/308)
   c. [ ] is not required, as the application was filed in the United States Receiving Office (RO/US).
6. [X] A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. [ ] Amendments to the claims of the International Aplication under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. [ ] are transmitted herewith (required only if not transmitted by the International Bureau).
   b. [ ] have been transmitted by the International Bureau.
   c. [ ] have not been made; however, the time limit for making such amendments has NOT expired.
   d. [ ] have not been made and will not be made.
8. [ ] A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371 (c)(3)).
9. [ ] An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. [ ] A translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern document(s) or information included:

11. [ ] An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. [ ] An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. [X] A FIRST preliminary amendment.
    [ ] A SECOND or SUBSEQUENT preliminary amendment.
14. [ ] A substitute specification.
15. [ ] A change of power of attorney and/or address letter.
16. [X] Other items or information:

    International Preliminary Examination Report.

    Application Data Sheet.

    Search Report.

    Form PCT/IB/308.

U.S. APPLICATION NO. (if known, see 37 CFR 1.5)	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
09/622639	PCT/FR99/00357	HORY 2.PCT/US

17. [X] The following fees are submitted:	CALCULATIONS PTO USE ONLY	
BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)):		
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO ..... $ 970.00		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO $840.00		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO $690.00		
International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) $670.00		
International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) $96.00		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 840	
Surcharge of $130.00 for furnishing the oath or declaration later than [ ] 20 [X] 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$ 130	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	
Total claims	12 - 20 =	0	x $18.00	$ 0
Independent claims	1 - 3 =	0	x $78.00	$ 0
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ $260.00	$
TOTAL OF ABOVE CALCULATIONS =				$ 970
Reduction of 1/2 for filing by small entity, if applicable. A Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28). +				$
SUBTOTAL =				$ 970
Processing fee of $130.00 for furnishing the English translation later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				$
TOTAL NATIONAL FEE =				$ 970
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +				$
TOTAL FEES ENCLOSED =				$ 970
			Amount to be refunded:	$
			charged:	$

a. [X] A check in the amount of $ 970 to cover the above fees is enclosed.

b. [ ] Please charge my Deposit Account No. _____ in the amount of $ _____ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. [X] The Commissioner is hereby authorized to charge any additional fees which may be required by 37 CFR 1.16 and 1.17, or credit any overpayment to Deposit Account No. 25-0120. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137 (a) or (b)) must be filed and granted to restore the application to pending status.

August 21, 2000

SEND ALL CORRESPONDENCE TO:

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Benoit Castel
SIGNATURE

Benoit Castel
NAME

3,041
REGISTRATION NUMBER

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of

Arnaud HORY et al.

Serial No. (unknown)

Filed herewith

RAPID PROTOTYPING PROCESS
BY LASER SINTERING OF
POWDER AND ASSOCIATED
DEVICE

PRELIMINARY AMENDMENT

Commissioner of Patents

Washington, D.C. 20231

Sir:

Prior to calculation of the filing fee, please amend the above-identified application as follows:

IN THE CLAIMS:

Claim 3, line 1, cancel "or 3".

Claim 4, line 1, cancel "or 3".

Claim 5, lines 1 and 2, change "any one of the preceding claims" to --claim 1--.

Claim 6, line 2, change "any one of the preceding claims" to --claim 1--.

Claim 8, line 1, cancel "or 7".

Claim 10, line 1, change "any one of claims 6 to 9" to --claim 6--.

Claim 11, line 1, change "any one of claims 8 to 10" to --claim 8--.

Claim 12, line 1, change "any one of claims 7 to 11" to --claim 7--.

Respectfully submitted,

YOUNG & THOMPSON

By Benoît Castel

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August 21, 2000

Form B

VERIFIED STATEMENT CLAIMING SMALL ENTITY STATUS (37 CFR 1.9(f) & 1.27(c))--SMALL BUSINESS CONCERN

Docket Number (Optional)

Applicant or Patentee: HORY Arnaud, GAILLARD Jean-Marie, ABELARD Pierre
Serial or Patent No.: UNKNOWN
Filed or Issued: on August 21, 2000
Title: FAST PROTOTYPING METHOD BY LASER SINTERING OF POWDER AND RELATED DEVICE.

I hereby declare that I am

☐ the owner of the small business concern identified below:
☒ an official of the small business concern empowered to act on behalf of the concern identified below:

NAME OF SMALL BUSINESS CONCERN ECOLE NATIONALE SUPERIEURE DE CERAMIQUE INDUSTRIELLE (ENSCI)
ADDRESS OF SMALL BUSINESS CONCERN 47-73 Avenue Albert Thomas
F-87065 LIMOGES Cedex (FRANCE)

I hereby declare that the above identified small business concern qualifies as a small business concern as defined in 13 CFR 121.12, and reproduced in 37 CFR 1.9(d), for purposes of paying reduced fees to the United States Patent and Trademark Office, in that the number of employees of the concern, including those of its affiliates, does not exceed 500 persons. For purposes of this statement, (1) the number of employees of the business concern is the average over the previous fiscal year of the concern of the persons employed on a full-time, part-time or temporary basis during each of the pay periods of the fiscal year, and (2) concerns are affiliates of each other when either, directly or indirectly, one concern controls or has the power to control the other, or a third party or parties controls or has the power to control both.

I hereby declare that rights under contract or law have been conveyed to and remain with the small business concern identified above with regard to the invention described in:

☐ the specification filed herewith with title as listed above.
☒ the application identified above.
☐ the patent identified above.

If the rights held by the above identified small business concern are not exclusive, each individual, concern or organization having rights in the invention must file separate verified statements averring to their status as small entities, and no rights to the invention are held by any person, other than the inventor, who would not qualify as an independent inventor under 37 CFR 1.9(c) if that person made the invention, or by any concern which would not qualify as a small business concern under 37 CFR 1.9(d), or a nonprofit organization under 37 CFR 1.9(e).

Each person, concern or organization having any rights in the invention is listed below:

☒ no such person, concern, or organization exists.
☐ each such person, concern or organization is listed below.

Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 CFR 1.27)

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28(b))

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

NAME OF PERSON SIGNING Christian GAULT
TITLE OF PERSON IF OTHER THAN OWNER Director of ENSCI
ADDRESS OF PERSON SIGNING 31, rue Camille Sée, 87000 LIMOGES (FRANCE)
SIGNATURE _____ DATE 05.09.2000

BP/SB/HORY 2.PCT/US

RAPID PROTOTYPING PROCESS BY LASER SINTERING OF POWDER AND ASSOCIATED DEVICE

The present invention has for its object a process for the rapid prototyping by powder sintering, particularly of ceramic powder, and a device for practicing said process.

Rapid prototyping is a process which permits obtaining pieces of complicated shapes without tools and without machining, from a three-dimensional image of the piece to be made, by sintering superposed layers of powder with the help of a laser.

A first prototyping process by laser sintering of powder is described in international patent application WO 96/06881. It permits particularly obtaining pieces of polymer by sintering in liquid phase polymeric powders. In this case, the temperature level generated by the laser is relatively low because the fusion temperatures of the polymers are not high, of the order of about 100°.

So as to obtain more resistant pieces of material, it is necessary, in this case, to use a so-called lost wax molding process.

This process for making a resistant piece is long and there is obtained a relatively mediocre dimensional precision for certain applications. Thus, numerous disper-

sions arising from the different processes do not permit obtaining precise dimensions of the order of ± 50 μm.

A second process consists in sintering in liquid phase a mixture of powder materials, one of the materials having a relatively low metal temperature of the order of several hundreds of degrees. Here again, the temperature level generated by the laser is relatively low because of the low melting temperature of one of the materials. It should be noted that the phenomenon commonly called sintering is a sintering in liquid phase and that it is more like cementing of grains, the material of a relatively low fusion temperature being used as a binder. In this case, the piece obtained is not homogeneous and the dimensional precision is relatively mediocre. Thus, the criterion of dimensional precision is not essential in this case because the operator can easily true by machining the dimensions of the pieces thus obtained.

Another process for rapid prototyping, described in U.S. Patent 5,182,170, consists in causing a powder material to react, disposed in successive layers, with a gas, by heating with the help of a laser. Thus, there can be obtained pieces from certain highly resistant ceramics thanks to chemical reactions of the nitriding or cementing type. But this process cannot be applied to all ceramics.

As can be seen, the processes of the prior art do not permit obtaining homogeneous pieces from sintered ceramic powders because the fusion temperatures of the ceramics are too high.

The devices associated with these processes comprise in general a target on which are disposed successively the layers of sintered powder, means for emplacing in layers the powder, as well as means to control the stroke of the laser. The produced piece is disposed on the upper surface of a piston which can move in a cylinder whose upper end constitutes the target.

These devices are in general used at temperatures that are not very high and do not permit obtaining pieces of precise dimensions.

However, for the production of ceramic pieces, a dimensional precision is an essential criterion because the truing of the dimensions obtained at the end of the process is possible only with the aid of a diamond tool, and remains reserved for simple point operations without involving machining.

The present invention therefore seeks to provide a process for rapid prototyping by laser sintering of any powder, and particularly ceramic powders.

It also provides the associated device, adapted to be used at high temperatures, around 900°C, and which permits obtaining by laser sintering of powders, a piece of high dimensional precision of the order of ± 50 μm, which is to say half the precision obtained by devices of the prior art.

To this end, the invention has for its object a process for rapid prototyping by sintering in solid phase,

with the help of a laser, of a powder of a mixture of powders, characterized in that it comprises the steps which consist in:

1/ obtaining a series of digitized superposed sections of an object to be produced, from a three-dimensional image of said object,

2/ spreading in the form of a fine layer the powder or the mixture of powders heated to a temperature near the sintering temperature in solid phase of said powder or said mixture of powders,

3/ increasing the density of the powder of the layer,

4/ bringing the layer to the sintering temperature by sweeping said layer with the help of a laser beam such that a sectioned portion of the powder, which corresponds to one of the digitized sections of the object to be produced, is sintered in solid phase thanks to the supplemental energy supplied by the laser,

steps 2, 3 and 4 being repeated until all the digitized superposed sections of the object to be produced are obtained.

Preferably, the powder or the mixture of the powders is heated and held at a temperature of the order of 300°C to 900°C, and the layer is mechanically compacted so as to increase its density.

Preferably, the laser used is a pulsed YAG laser, and the wavelength of the emitted radiation is in the near infrared.

The invention also has for its object a device for practicing said process, characterized in that it comprises a laser having control means for the stroke, in turn controlled by a computer interface, a high temperature cell provided with heating means and a target for a laser beam, a means for layering, disposed in said cell, adapted to deposit on the target a layer of powder.

According to a preferred embodiment, it comprises compacting means, disposed in the high temperature cell, adapted to compact the layer being sintering.

Other characteristics and advantages will become apparent from the description of a preferred embodiment, which description is given by way of example only, with reference to the accompanying drawings, in which:

- Figure 1 is a schematic diagram of the principle of the process of the invention,

- Figure 2 is a longitudinal cross-section of the device according to the invention,

- Figure 3 is a transverse cross-section of the device, and

- Figures 4A to 4E show a synopsis of the operation of the device.

According to the invention, the process for rapid prototyping by laser sintering of a ceramic powder or of a mixture of ceramic powders, comprises the steps which consist in:

1/ obtaining a succession of digitized superposed sections 10 of an object 12 to be produced, from a three-dimensional image of said object,

2/ spreading in the form of a fine layer 14 ceramic powder or a mixture of ceramic powders heated to a temperature near the sintering temperature in solid phase of said powder or mixture,

3/ increasing the density of the powder of the layer 14,

4/ bringing the layer to the sintering temperature by sweeping said layer with the help of a laser beam 16 such that a selected portion 18 of the powder, which corresponds to one of the digitized sections 10' of the object 12 to be produced, is sintered in solid phase thanks to the energy of the laser.

Steps 2, 3 and 4 are repeated until all the digitized superposed sections of the object to be produced are obtained.

This process of rapid prototyping by laser sintering can be used for sintering any ceramic powder or mixture of powders.

During step 1, the object 12, shown by a digitized image in three dimensions, is sliced with the help of software so as to obtain a series of digitized superposed sections 10.

During step 2, the ceramic powder or the mixture of ceramic powders is spread in the form of a fine layer 14 of a thickness of the order of 200 μm. The ceramic powder or the

mixture of ceramic powders is first heated and held at a temperature of 900°C during the process so as to increase the rapidity of production of the object and to reduce the energy supplied by the laser 16 as will be explained.

During step 3, the density of the layer 14 is increased so as to decrease its porosity, by compacting it for example. There is thus obtained a layer 14 of a thickness of the order of 100 μm.

During step 4, the solid phase sintering of a selected portion 18 of the layer 14 is carried out by directing the laser beam 16 such that it reproduces one of the digitized superposed sections 10'. According to the process, solid phase sintering is used, which is to say that the sintering temperature remains below the fusion temperature of the ceramic powders used.

Thus, during sintering, in a first instance, connection regions, called grain joints, form between the particles in contact, then in a second instance, the residual porosity between the grains disappears thanks to the phenomena of diffusion and plastic flow. This sintering is the more rapid the more the sintered powder is first compacted and heated.

Thus, by heating the powder, the laser energy serves only to supply the quantity of heat necessary to raise the temperature of the powder from 900°C to the sintering temperature. Because of this, the energy supplied by the laser is

reduced and the speed of production of the object is increased.

Similarly, by first compacting the layer 14 of ceramic powder, the porosity of the powder is decreased, which permits having at the beginning of sintering a lesser residual porosity, which also contributes to increasing the speed of production.

Preferably, the laser used is a pulsed YAG laser, and the emitted radiation wavelength is in the near infrared. More precisely, the laser beam has a wavelength of 1064 nm.

For ceramic powders which do not absorb infrared radiation, there is used a dopant, for example zirconium silicate, such that the mixture thus obtained absorbs the infrared radiation emitted by the laser.

In Figures 2 and 3, there is shown a device 20 for practicing a process of rapid prototyping by laser sintering of ceramic powder. It is associated with a computer interface (not shown) which permits, starting from a three-dimensional image of the object to be produced, slicing said object into several layers. This interface is adapted also to control the various elements of the device 20 as will be described hereafter.

The device 20 comprises a frame 22, disposed below a laser 24, and a horizontal plate 26 disposed in part above the frame 22, and whose upper surface 28 defines a working plane.

The laser 24 comprises means 30 for controlling the stroke, subject to the computer interface, which permits particularly directing the ray 32.

These control means 30 for the stroke are known to those skilled in the art, and form no part of the present application.

The plate 26 comprises two cylindrical openings 34, 36 which are prolonged below the plate 26 by a first cylinder 38 and a second cylinder 40 whose internal diameters are equal to those of the openings 34, 36. Each cylinder is fixed by a small collar 42 to the lower surface of the plate 36 by securement means (not shown), screws for example.

The first cylinder 38, prolonged by the opening 34, is called the working cylinder. It is disposed below the laser beam 32, and its upper end, which is flush with the working plane 28, defines a target 43 for said beam. Similarly, the second cylinder 40, prolonged by the opening 36, and disposed adjacent the first cylinder 38, serves as a reservoir for first powdered ceramic material.

Pistons 44, 46 are provided to move in translation respectively in the cylinders 38, 40. Each piston 44, 46 is fixed to the upper end of a rod 38, whose lower end is fixed to an arm 50 connected to means 52 and 54 for controlling the pistons 44, 46, respectively. These control means 52 and 54, in the form for example of a stepping motor, are subject to the computer interface which controls the rising and falling of said pistons.

Means 56 for measuring the real height of the upper surface of the piston 44 are provided, to compensate dimensional disparities arising from mechanical connections and/or deformation by expansion of the different elements, so as to obtain a dimensional precision of the order of ± 50 μm. These measuring means 56 are formed by an optically read scale 58, which is vertical, and fixed to the frame 22 adjacent the working cylinder 38.

Above the plate 26, a thermally insulated chamber 60 permits delimiting with the plate 26 a high temperature cell 62. The plate 26 is connected to the frame 22 by insulating connection means 64 which permit limiting the propagation of deformations due to expansion of the plate 26 toward the frame 22. According to a preferred embodiment, these insulating connecting means 64 comprise on the one hand balls 66 disposed in the upper portion of the frame 22, on which the plate 26 rests, and on the other hand pins 68, fixed to the sides of the plate 26, which rest in recesses 70 of the frame 22 as seen in Figure 3.

In addition, a layer 72 of insulating materials is disposed below the plate 26 so as to render the high temperature cell 62 as adiabatic as possible.

On the other hand, heating means 74, in the form of a resistance, are disposed inside the cell 62, so as to heat the atmosphere of the cell to a temperature of the order of 900°C. In addition, temperature control means 76, in the form

of a thermocouple, permit regulating the temperature within the cell.

A window 78, of a diameter substantially equal to the working cylinder 38, is provided in a thermally insulated chamber 60 in line with the beam 32 and the working cylinder 38. This window 78, which is thermally insulated, comprises filtering means 80, which let pass the near infrared radiation of the laser toward the working cylinder 38, but which filter out radiation emitted by the black body which constitutes the high temperature cell 62, toward the laser 24. These filtering means 80 permit limiting the heating of the head of the laser 24 during its operation. They are comprised by two superposed lenses 82, adapted to resist high temperatures, disposed in a lens support 84.

On the working plane 28, means 68 for forming a layer and means 88 for compacting, can move in the direction defined by the right angle line connecting the centers of the cylinders 38, 40.

The layering means 86, comprised by a screed 90, permit transferring the ceramic powder from the reservoir 40 toward the working cylinder 38, so as to deposit the powder in the form of successive layers 92 of equal thicknesses in the working cylinder 38.

The compacting means 88, in the form of a compacting roller 94, permit compacting the powder of the layer 92 before its sintering.

Two rods 96, disposed at each end of the roller 94, permit connecting the screed 90 to the compacting roller 94 which is fixed to an arm 98 connected to control means 100 for the layering means 86 and compacting means 88. These control means 100, in the form for example of a stepping motor, are also controlled by the computer interface which at the same time controls the movements of the pistons 44, 46, the movements of the screed 90 and of the roller 44 as will be explained hereafter.

A recess 102 is also provided in the working plane 28 beside the opening 34, diametrically opposite the opening 36. This recess is adapted to recess the surplus powder when the screed 90 transfers the powder from the reservoir 40 to the working cylinder 38.

The operation will now be described with respect to Figures 4A to 4E.

In Figure 4A, there is schematically shown the device in phase 0 of the process. During this phase, piston 44 of the working cylinder descends by 200 μm, whilst the piston 46 of the reservoir 40 rises by 200 μm so as to dispose a volume 104 of ceramic powder above the working plane 28.

During phase 1, shown in Figure 4B, the screed 90 pushes the volume 104 of ceramic powder, and spreads it uniformly in the form of a layer 106 in the working cylinder 38. The volume 104 of powder must be sufficient to avoid a shortage of powder in the working cylinder 38, and to obtain a layer 106 which is flush with the working plane 28.

During phase 2, shown in Figure 4C, the screed 90 has finished spreading the quantity 104 of powder, and the roller 92 is located at point A at the surface of the layer 106 adjacent a first point of tangency 108 of said roller with the working cylinder 38. At this time, the piston 44 of the working cylinder 38 rises by 100 μm such that a portion of the layer 106 is disposed above the working plane. The roller 92 then compacts a region 110 of the layer 106 which extends from point A to point B located at the surface of the layer 106 adjacent a second point of tangency 112 of said roller with the working cylinder 38.

During phase 3, shown in Figure 4D, the piston 44 of the working cylinder descends by 100 μm, to avoid compacting the edges of the working cylinder 38. The roller 92, as well as the screed 90, return to the initial position show in Figure 4A.

During phase 4, shown in Figure 4E, the ceramic powder in the compacted region 110 is sintered according to the process of the invention, so as to obtain the shape of the object. After sintering, the piston of the working cylinder descends by 100 μm, and the piston 46 of the reservoir rises by 200 μm, so as to place a new volume 104' of ceramic powder above the working plane 28 and to return to phase 1.

Thus, the phases 1, 2, 3 and 4 are repeated for each new layer until the desired object is obtained. During all these phases, the heating means 74 maintains the cell 62 at a temperature of the order of 900°C. Thus, the sintered powder

is already at a temperature of the order of 900°C, which permits limiting the quantity of energy necessary for sintering and to increase the speed of production of the object.

The process of the invention and the associated device have been described for the production of pieces from ceramic powder, but there can be envisioned, in exactly the same way, by simple adaptation of the different parameters, their use for obtaining pieces of any material, and particularly from metallic powders.

C L A I M S

1. Process for the rapid prototyping by sintering in solid phase, with a laser, of a powder or mixture of powders, particularly ceramic, characterized in that it comprises the steps which consist in:

1/ obtaining a series of digitized superposed sections (10) of an object (12) to be produced, from a three-dimensional representation of said object,

2/ spreading in the form of a thin layer (14) the powder or mixture of powders heated to a temperature near the sintering temperature in solid phase, of said powder or said mixture of powders,

3/ bringing the layer (14) to the sintering temperature by sweeping with a laser beam (16) said layer such that a selected portion (18) of the powder, which corresponds to one of the digitized sections (10') of the object (12) to be produced, is sintered in solid phase thanks to the supplemental energy supplied by the laser,

the steps 2 and 3 being repeated until all the digitized superposed sections of the object to be produced are obtained.

2. Process according to claim 1, characterized in that it comprises the steps which consist in:

1/ obtaining a series of digitized superposed sections (10) of an object (12) to be produced, from a three-dimensional representation of said object,

2/ spreading in the form of a thin layer (14) the powder or mixture of powders heated to a temperature near the sintering temperature in solid phase of said powder or said mixture of powders,

3/ increasing the density of the powder of the layer (14),

4/ bringing the layer (14) to the sintering temperature by sweeping with a laser beam (16) said layer such that a selected portion (18) of the powder, which corresponds to one of the digitized sections (10') of the object (12) to be produced, is sintered in solid phase by the supplemental energy supplied by the laser,

the steps 2, 3 and 4 being repeated until all the digitized superposed sections of the object to be produced are obtained.

3. Process according to claim 2 or 3, characterized in that the powder or mixture of powders is heated and held at a temperature of the order of 300°C to 900°C.

4. Process according to claim 2 or 3, characterized in that the layer (14) is mechanically compacted so as to increase its density.

5. Process according to any one of the preceding claims, characterized in that the laser which is used is a pulsed YAG laser, and that the wavelength of the emitted radiation is in the near infrared.

6. Device for practicing the process according to any one of the preceding claims, characterized in that it comprises a laser (24) provided with means (30) for controlling the stroke subject to a computer interface, a high temperature cell (32) provided with heating means (74) and a target (43) for a beam (32) of the laser (24), and means (86) for laying down in layer form, disposed in said cell (62), adapted to deposit on the target (43), a layer (92) of powder.

7. Device according to claim 6, characterized in that it comprises compacting means (88), disposed in the high temperature cell (62), adapted to compact the layer (92) before sintering.

8. Device according to claim 6 or 7, characterized in that the cell (62) is delimited in its lower portion by a horizontal plate (26) which comprises two openings (34, 36), prolonged below the plate (26) by first and second cylinders (38, 40), in each of which can move a piston (44, 46), the first cylinder (38), disposed in prolongation of the beam (34), constituting the target (43), and the second cylinder (40), disposed adjacent the first, constituting a reservoir of first material in powder form, and in that the means (86) for laying down a layer are adapted to transfer the powder from

the second cylinder toward the first, so as to deposit it in the form of a layer (92), the compacting means (88) being adapted to compact said layer (92).

9. Device according to claim 8, characterized in that the two pistons (44, 46) are provided respectively with control means (52, 54) subject to the computer interface.

10. Device according to any one of claims 6 to 9, characterized in that the high temperature cell (62) is delimited in its upper portion by a thermally insulating chamber (60) which comprises a window (78), in prolongation of the laser beam (32), provided with filter means (80) in the form of at least one lens (82), which let pass near infrared radiation of the laser to the interior of the cell (62) but which filter out radiation emitted by the black body constituted by the cell (62) toward the laser.

11. Device according to any one of claims 8 to 10, characterized in that it comprises means (56) for measuring the real height of the piston (44), disposed in the first cylinder (38).

12. Device according to any one of claims 7 to 11, characterized in that the compacting means (88) are in the form of a roller (94), and the layer forming means (86) by a screed (90), connected to said roller (94), the two means (86, 88) being controlled by control means (100) subject to the computer interface.

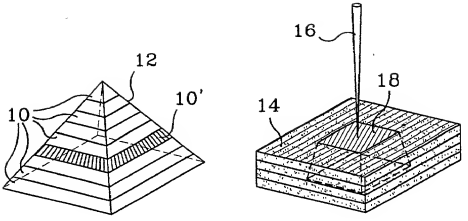


FIG.1

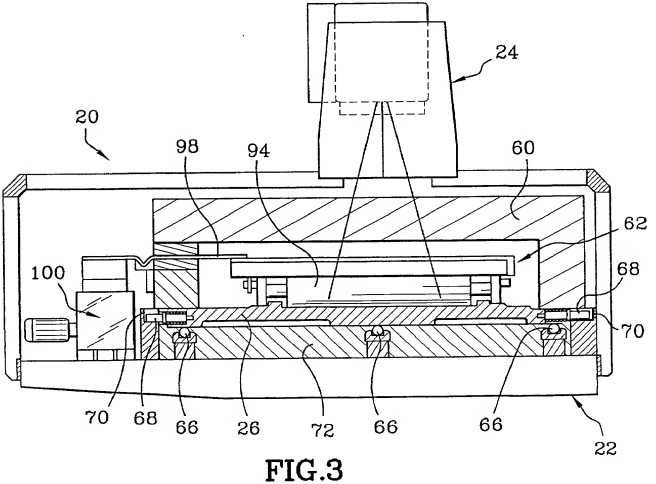
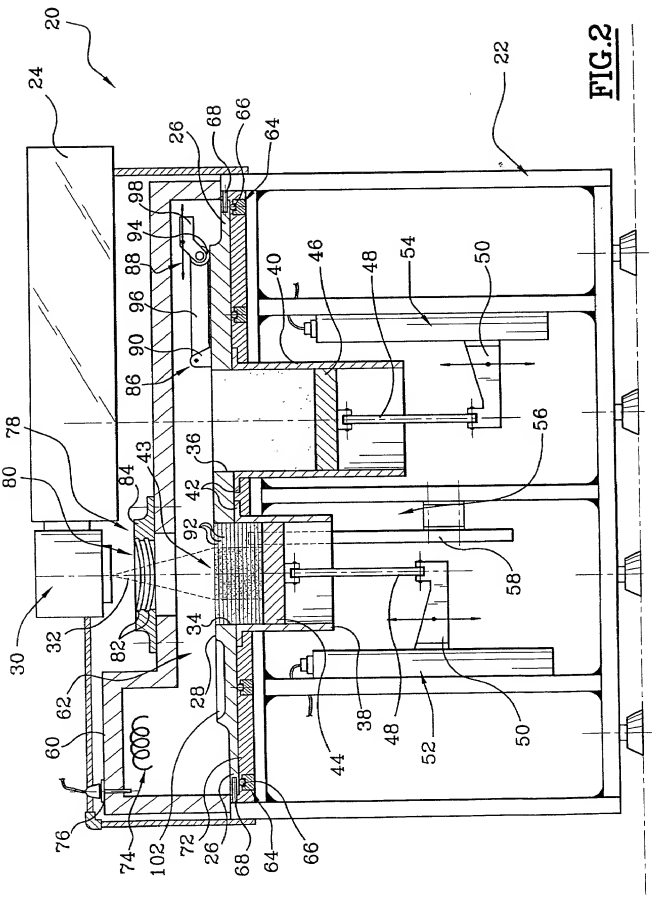


FIG.3


20
24
22
26
68
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64
98
94
88
96
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86
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78
80
84
43
36
42
92
56
58
30
32
82
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62
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38
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48
52
50
76
74
102
72
26
68
64
66

FIG.2

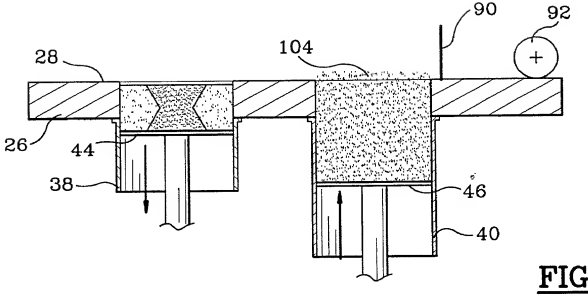

FIG.4A

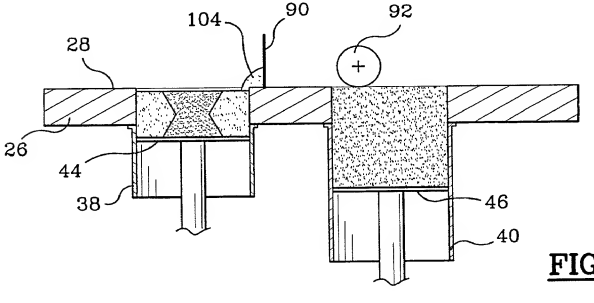

FIG.4B

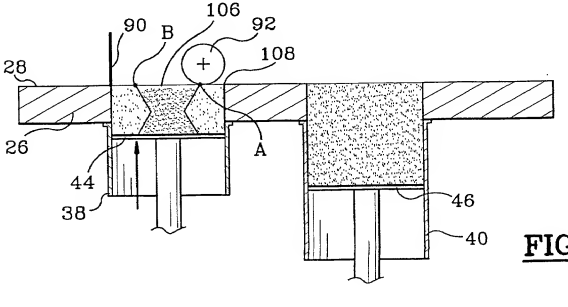

FIG.4C

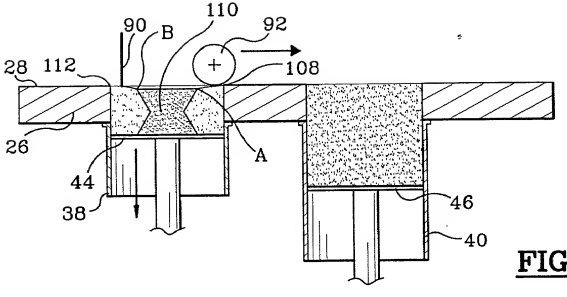
110
90
B
92
28
112
108
26
A
44
38
46
40

FIG.4D

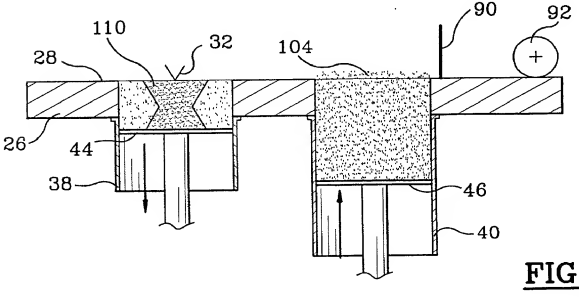
90
92
110
32
104
28
26
44
38
46
40

FIG.4E

COMBINED DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

FAST PROTOTYPING METHOD BY LASER SINTERING OF POWDER AND RELATED DEVICE

the specification of which: *(check one)*

REGULAR OR DESIGN APPLICATION

[ ] is attached hereto.

[ ] was filed on as application Serial No. and was amended on (if applicable).

PCT FILED APPLICATION ENTERING NATIONAL STAGE

[X] was described and claimed in International application No. PCT/FR99/00357 filed on 17 February 1999 and as amended on (if any).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

PRIORITY CLAIM

I hereby claim foreign priority benefits under 35 USC 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed.

PRIOR FOREIGN APPLICATION(S)

Country	Application Number	Date of Filing (day, month, year)	Priority Claimed
France	**98 02217**	**19 February 1998**	**yes**

(Complete this part only if this is a continuing application.)

I hereby claim the benefit under 35 USC 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of 35 USC 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37 Code of Federal Regulations §1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Serial No.) (Filing Date) (Status--patented, pending, abandoned)

POWER OF ATTORNEY

The undersigned hereby authorizes the U.S. attorney or agent named herein to accept and follow instructions from **Cabinet Thebault** as to any action to be taken in the Patent and Trademark Office regarding this application without direct communication between the U.S. attorney or agent and the undersigned. In the event of a change in the persons from whom instructions may be taken, the U.S. attorney or agent named herein will be so notified by the undersigned.

As a named inventor, I hereby appoint the registered patent attorneys represented by Customer No. **000466** to prosecute this application and transact all business in the Patent and Trademark Office connected therewith, including: **Robert J. PATCH, Reg. No. 17,355, Andrew J. PATCH, Reg. No. 32,925, Robert F. HARGEST, Reg. No. 25,590, Benoît CASTEL, Reg. No. 35,041, Eric JENSEN, Reg. No. 37,855, Thomas W. PERKINS, Reg. No. 33,027, and Roland E. LONG, Jr., Reg. No. 41,949,**

c/o YOUNG & THOMPSON,
Second Floor,
745 South 23rd Street,
Arlington, Virginia 22202.

Address all telephone calls to Young & Thompson at 703/521-2297. Telefax: 703/685-0573.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Inventor's signature _____ Date 04 09 00

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